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TECHNICAL MEMORANDUM No. 204/M/47

A Hydrometer for the Rapid Measurement of the Density of Plastic Propellant

A. J. C. Nicholson, P. R. Freeman and D. F. Runnicles

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Waltham Abbey, Essex.

April, 1947

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CHEMICAL RESEARCH AND DEVELOPMENT DEPARTMENT

C.R.D.D. TECHNICAL MEMORANDUM No. 204/M/47

A HYDROMETER FOR THE RAPID MEASUREMENT OF THE DENSITY OF PLASTIC PROPELLANT.

BY

A.J.C.NICHOLSON, P.R.FREEMAN AND D.F. RUNNICLES.

WALTHAM ABBEY.
ESSEX

APRIL 1947.

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I. REFERENCES

R.N.P.F. Technical Report No.106/F/2.
A.R.D. Explosives Report No.589/44.

S. No.7

II. SUMMARY

1. Object of Investigation.

To develop a method of measuring propellant density that will give an accurate control and can be carried out sufficiently rapidly to check the density of the deaerated propellant immediately after delivery from the pug-mill.

2. Result of the Investigation.

A hydrometer is described which will measure density on a 100 gm. sample to an accuracy of 1 part in 1000 without the need for accurate temperature control. The whole measurement can be made easily in five minutes. In an appendix, values of constituent densities are given so that the density of any propellant can be calculated from its composition.

III. TECHNICAL MATTER

1. Apparatus.

The hydrometer (Drawing A.R.D.6965A) consists of a glass float chamber attached to a framework carrying a graduated stem and a container with a wire mesh bottom. This apparatus is a modification of a design used for cordite described in R.N.P.F. Technical Report No. 106/F/2.

The liquid used is paraffin oil (kerosene). It has a density of 0.803 gm/ml at 20°C which decreases by 0.0007 gm/ml per 1°C rise in temperature. Both ammonium picrate and sodium nitrate have a negligible solubility in kerosene but polymeths is appreciably soluble. This causes a slow increase in the density of the liquid which is discarded when the density reaches 0.806 gm/ml at 20°C. Despite this disadvantage, kerosene was the most suitable of several liquids tested for this purpose.

2. Discussion.

The stem of the hydrometer is so calibrated that the density of the propellant can be obtained by a procedure which is essentially as follows:-

(a) Take the stem reading with a calibrating weight in position.

(b) Take the stem reading with X gms of plastic propellant in the container, X gms being such that a plastic of theoretical density (i.e. that calculated from the densities of its constituents) would give the same reading as in (a).

(c) The difference between the two readings gives the number of units in the third place (0.001 gm/ml) by which the density of the sample differs from the theoretical density.

The calibrating weight consists of a brass cylinder containing an axial hole by means of which it can be supported on the top of the hydrometer stem. The weight of the cylinder (53.905gm) is such that a reading is obtained on the stem of the instrument.

The value X for a plastic propellant of theoretical density ρ gm/ml can be calculated as follows:-

$$x - \text{hydrostatic upthrust} = 53.905 \text{ gm.}$$

$$\therefore\ x = 53.905 + \frac{Xd}{\rho} \qquad \text{where d is the density of the kerosene.}$$

$$\therefore\ x = \frac{53.905}{(1 - d/\rho)} \qquad \text{-----------------------------(1)}$$

/Example.

Example.

RD 2043 = 1.730.

d	0.800	0.801	0.802	0.803	0.804	0.805	0.806	0.807
x	100.28	100.38	100.49	100.60	100.71	100.82	100.93	101.04

Since it is inconvenient to weigh out an exact quantity of the propellant, a weight of x ± 0.5 gm is actually used and a correction is applied. This correction, S, may be obtained as follows:-

Suppose a weight W (greater thanx) gms of Plastic propellant is taken. The additional immersion of the stem will be due to a weight of (W-x) gms. less the hydrostatic upthrust due to the additional quantity of propellant.

$$\text{Hence additional immersion of stem} = \frac{(W-x)-(W-x)d/\rho}{d} \text{ mls}$$

$$= \frac{(W-x)(\rho - d)}{\rho\, d} \text{mls}$$

Each stem division corresponds to 0.0298 ml (see "Calculation of Stem Calibration".

Hence if additional immersion of the stem is S divisions:-

$$S \times 0.0298 = \frac{(W-x)(\rho - d)}{\rho\, d}$$

$$\text{and } S = \frac{(W-x)(\rho - d)}{0.0298\, \rho\, d} \quad \text{-----------------------------(2)}$$

For each type of propellant x must be calculated from (1) and substituted in (2). This gives a linear relationship between S and W for a particular value of d. Using different values of d, a series of almost parallel straight lines are obtained from which the correction of S may be read off for any particular value of W & d.

The convention is used that the top stem graduation is 0 and increases down the stem. Hence if W is greater than x, the correction must be subtracted and if W is less than x, the correction must be added.

Plots of S against W for RD 2043 are attached (Fig.1).

3. Density of the Liquid.

An error of 1 part in 800 in measuring the density of the liquid causes an error of 0.002 gm/ml in the propellant density. This is too large to be neglected and hence the hydrometer itself is used as a very sensitive instrument for the liquid. A reading is obtained on the stem of the hydrometer by placing suitable brass weights in the container and a graph is provided from which the density of the kerosene can be read from the stem reading obtained and the brass weights used. It is necessary occasionally to check the density with an independent hydrometer.

The stem reading with the calibrating brass weight on the stem and the appropriate weights in the container, is read before and after each determination. If a change in temperature occurs during the determination the two readings will differ and "d" is calculated from the mean reading.

/4.

4. Density of the Propellant.

It has been found that the density of plastic propellant has a temperature coefficient of about 0.0005 gm/ml/°C. For routine testing, it is not considered necessary to use any special temperature control or to apply a temperature correction.

5. Calculation of the Stem Calibration.

Consider R.D.2043, for which an average value of x is 100.8 gms and the theoretical density is 1.730 gms. A sample of 100.8 gms of density 1.729 will have a larger volume than the theoretical value by:-

$$\frac{100.8}{1.729} - \frac{100.8}{1.730} = 0.0337 \text{ ml.}$$

Hence, for use with RD.2043, one stem division should correspond to 0.0337 ml.

The corresponding figures for other propellants are:-

RD.	2633	0.0286
RD.	2200	0.0312
RD.	2030	0.0313
RD.	2073	0.0420

The actual stem used is 0.0298 ml per division. This approximates to the stem volume required for RD. 2633, which is the densest propellant so far made. With other propellants the stem volume is too low, so that the density figure obtained by this method may also be too low. The maximum error occurs with RD. 2073, with which a figure of 0.010 to be subtracted from the theoretical density would be indicated as 0.014. Since the errors involved make the density determination a more stringent test for the air content of the propellant, it is not usual to apply a correction for the stem volume, although this could easily be done if required.

6. Method of Operation.

The complete operation for the determination of the density of a sample of plastic propellant by this method may now be summarised:-

(i) Take a stem reading (A_1) using the brass calibrating weight on the stem and the appropriate brass weights in the container to give a reading on the stem.

(ii) Accurately weigh a sample of the propellant having a weight $W = x \pm 0.5$ gm., where x is the appropriate value for the propellant under test.

(iii) Take a stem reading (A_2) with the sample in the container.

(iv) Take a stem reading (A_3) exactly as in (1).

(v) From the mean value of A_1 and A_3, obtain the density of the kerosene, d, from the graph.

(vi) From d and W obtain the value of the stem correction, S, from the graph.

(vii) The difference between (A_2 + S) and (A_1 + A_3)/2 gives the number of units in the third place by which the density of the sample differs from the theoretical value.

IV. APPENDIX I.

It has been shown (A.R.D.Explosives Report No.589/44) that the density of a propellant can be calculated with sufficient accuracy from the densities

/of

of its constituents by assuming that the propellant is a simple mixture. In the Table below, the densities of the constituents and of some of the most important propellants are given. From these values the theoretical density of any propellant of known composition can be calculated. It should be remembered that the density of a mixture is not the arithmetic mean of the constituent densities but for a mixture A% by weight of a component of density "a" and (100-A)% by weight of a component of density "b", the density is given by:-

$$\text{Density AB} = \frac{100}{\frac{A}{a} + \frac{100-A}{b}}$$

No.	Composition	Density (gms/ml at 20°C)
	Ammonium picrate	1.720
	Sodium nitrate	2.261
	Nitroguanidine (picrite)	1.757
	Polystyrene (Distrene 80)	1.051
	Potassium nitrate	2.109
	Diethyleneglycol dinitrate	1.385
	D.E.G.D.N. saturated with water	1.382
	Polymeths (varies slightly from to sample)	1.000
	Ammonium perchlorate	1.954
	Lecithin	1.03
	Carbamite	1.05
	Lissapol L.S.	1.8
B.224	17½% N.C. in DEGDN	1.431
B.337	10% cellulose acetate butyrate in DEGDN	1.37
B.118	25% polystyrene in polymeths	1.018
B.116	30% polystyrene in polymeths	1.020
B.233	30% polystyrene in dibutyl phthalate	1.05
RD.2633	15% B.224, 42% AmPic, 42% $NaNO_3$ 1% carbamite	1.833
RD.2030	10% B.116	1.774
RD.2043	10% B.116	1.730
RD.2073	16% B.116, 40% Picrite, 15% $NaNO_3$, 18% AmPic, 1% Lecithin	1.605
RD.2200	10% B.116, 89% $AmClO_4$, 1% Lecithin.	1.776

V. APPENDIX 2.

Drawing No.A.R.D. 6965A.
Fig. 1.
Fig. 2.

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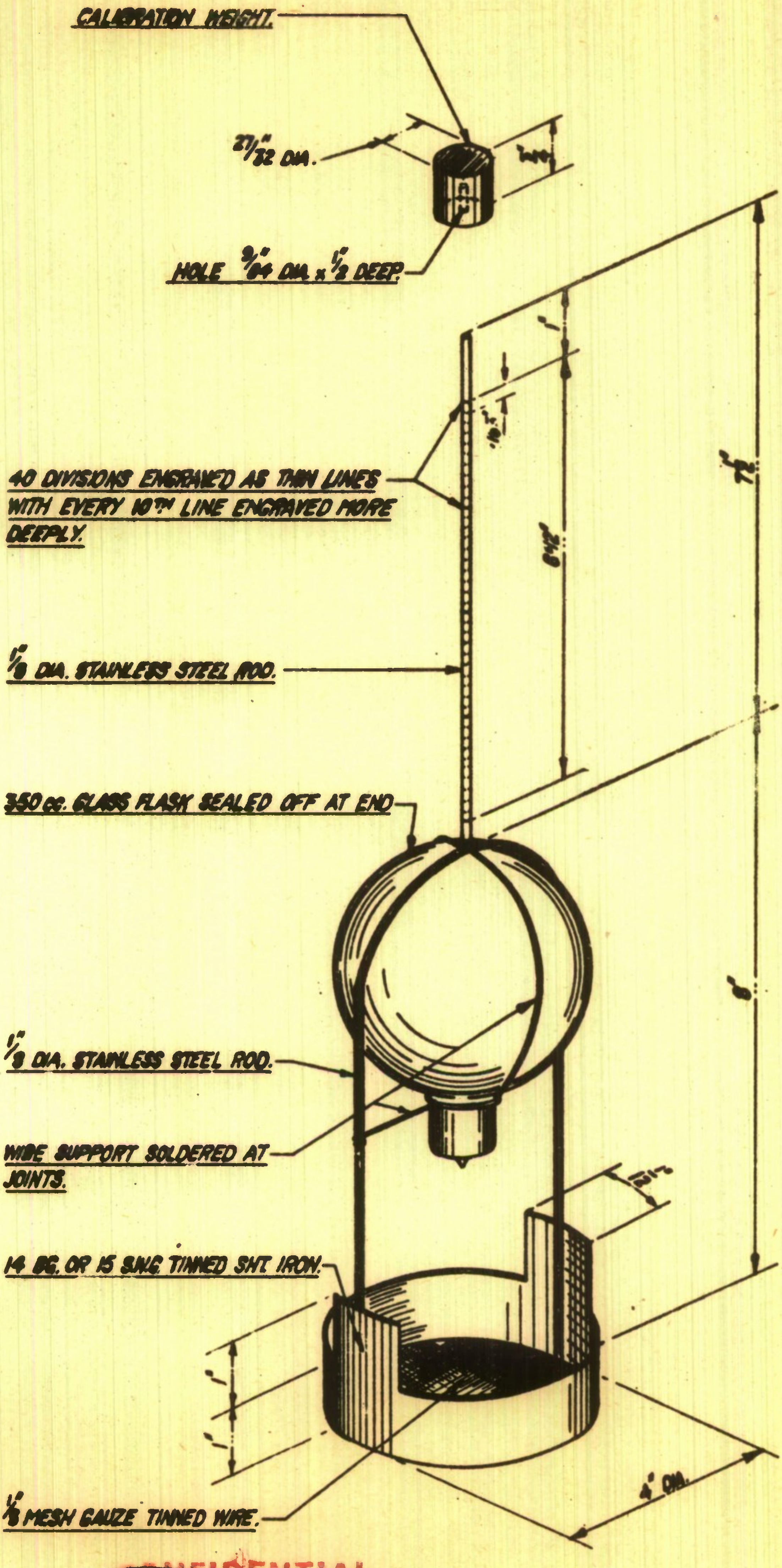

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STEM CORRECTIONS FOR PLASTIC PROPELLANT HYDROMETER

USING R.D. 2043

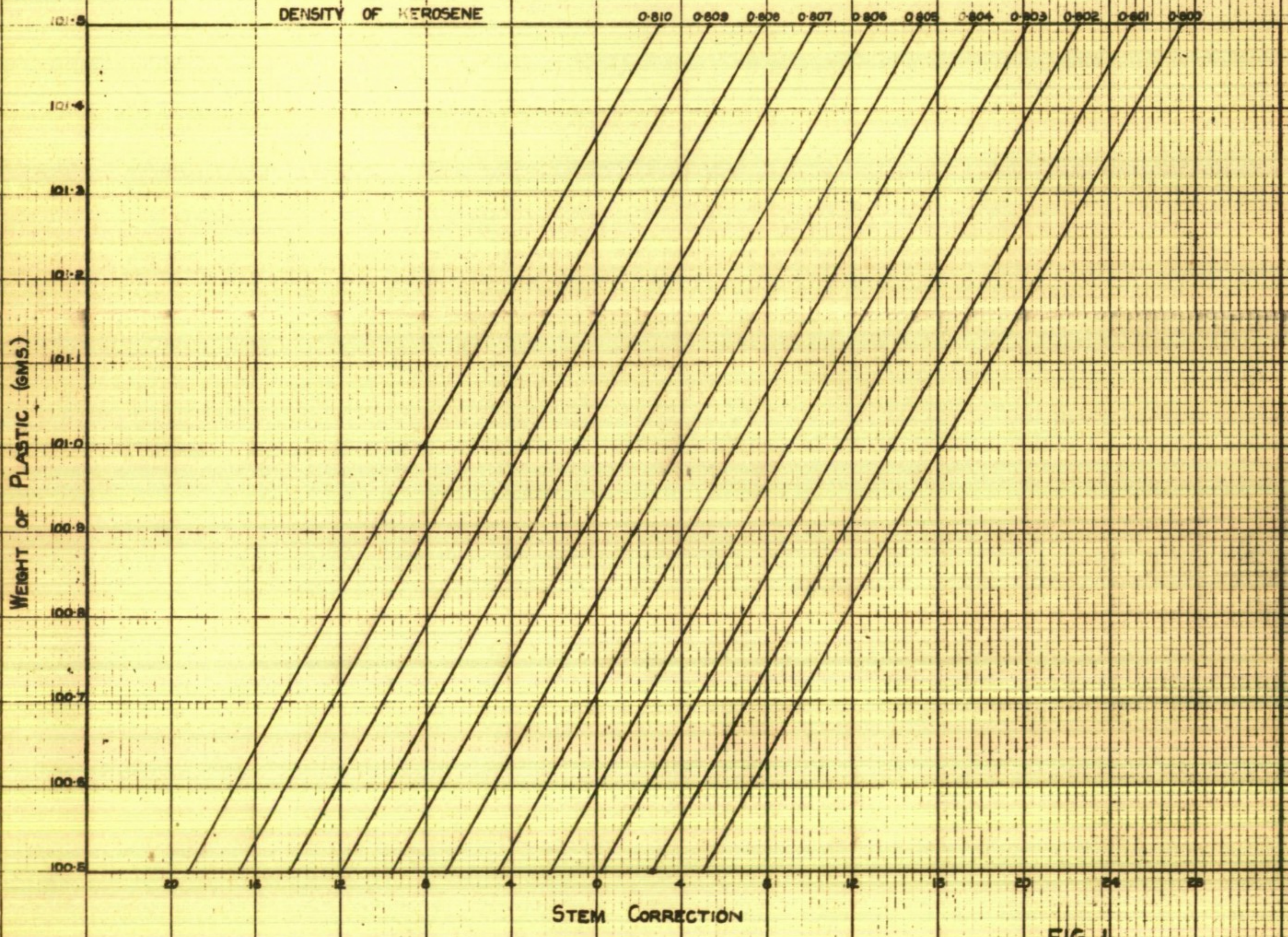

FIG. I

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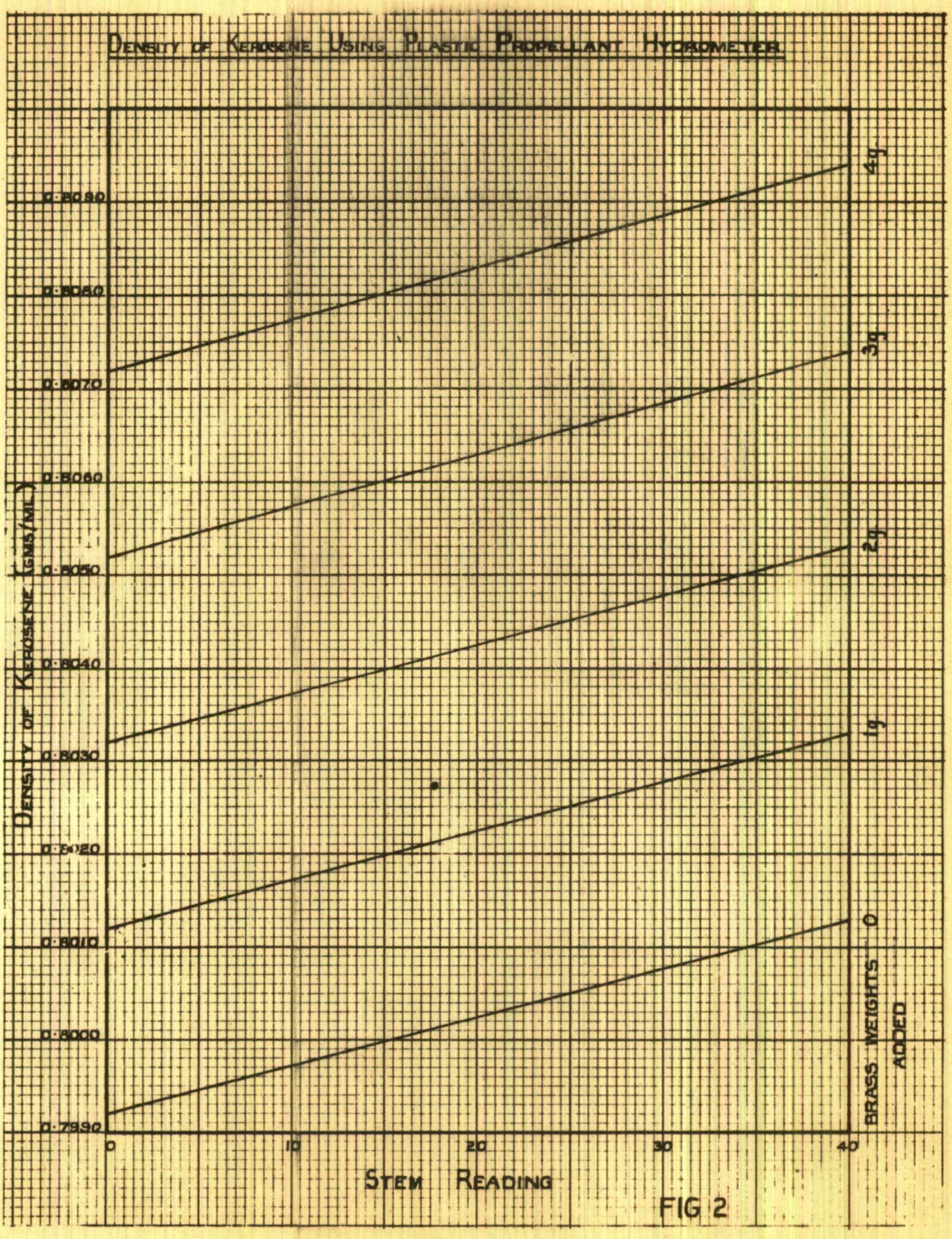

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Record Summary:
Title: Hydrometer for rapid measurement of density of plastic propellant
Covering dates 1947 Apr.
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
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